Weather forecast report

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Summary

During this report it has been done a weather forecast of *Saint Petersburg* using the a *Weather Research and Forecasting* model. It has been selected and analyse different variables in order to do a proper prediction of the weather.

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1 Introduction

The beggining of atmospheric modelization start with *Vilhelm Bjerknes*, who in 1904 had state a meteorolgy forecast as a Initial Value Problem based on 7 equations. These equations are a simplification of the **Navier Stokes** equations [1]. In fact, if we neglect the effect of viscosity in these equations, we obtain the **Euler** equations (non-linear equations) which are composed of the **Newton** equations, the equation of thermodynamics (conservation of energy), the continuity equation and the ideal gas law. In addition to these, some more equations are added, such as the conservation equations for water vapour. With this set, we are able to represent various atmospheric processes at different scales. However, since the solution of these is still very complex, simplifications such as the hydrostatic or a barotropic approximation are used.

The complexity of the weather forecast begin with the fact that for the dynamical system obtained there are not known solutions. Then, the problem have to be solved numerically, doing a proper discretization of the space and time for solving the differential equations. For instance, different space discretization strategies can be applied, as Arakawa C-grid or Eta coordinates.

Moreover, due to limitations in the grid size some phenomena produced in small scales were not well resolved producing wrong forecasts. In order to improve this predictions it has been used the parametrizations.

The first numerical model developed for weather forecasting was by Lewis Fry Richardson, who in 1922 attempted to calculate by hand the change in pressure and winds over two points in central Europe. Since 1922, along with the improvement and increase in physical observations due to the increased accuracy of tools such as satellites, for example, as well as scientific advances, models have improved significantly. Much of this progress has also been driven by the increase in computing power.

In this work we will use the Weather Research and Forecasting (WRF) model with the objective of forecasting the weather for the day 06/10/21 in the city (and surroundings) of St. Petersburg (Rusia).

2 WRF model

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers.

The effort to develop WRF began in the latter 1990's and was a collaborative partnership of the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the Earth System Research Laboratory), the U.S. Air Force, the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA) [2].

The WRF structure of the simulation used in this practical case will be in the simplest form without observational data assimilation. There are three main steps to running the WRF Preprocessing System (WPS):

- `geogrid.exe`: creates terrestrial data (static).
- `ungrib.exe`: unpacks GRIB meteorological data and packs it into an intermediate file format.
- `metgrid.exe`: interpolates the meteorological data horizontally onto your model domain.

Then, the output obtained from `metgrid.exe` is used as input for the WRF model. Here we can distinguish two main programs:

- `real.exe`: vertically interpolates the data onto the model coordinates.
- `wrf.exe`: generates the model forecast.

3 Results

In this work we will make a weather forecast for an arbitrarily chosen day for the city of St. Petersburg (Russia). In order to do this, before running our WRF model, we have to make a number of modifications. On the one hand, as we have explained in the previous section (WPS), we have to define both the location of the site by latitude/longitude and the time period over which we want to run our forecast. These two modifications will be made in the `namelis.wps` file.

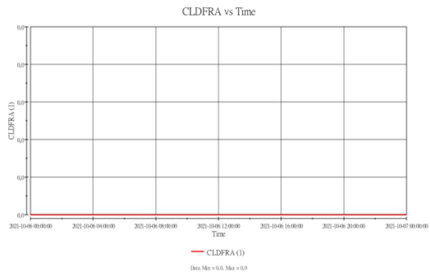
Then, we will run the model by executing the file `run_forecast.sh` and will generate an output file with all the variables needed to generate our prediction. Among all the variables exported by the model, 7 of them will be sufficient for our analysis:

- **CLDFRA**: total cloudiness (Fraction).
- **RAINNC**: non-convective max hourly precipitation rate in [kg m-2 s-1].
- **RAINC**: convective precipitation in [kg m-2 s-1].
- **Q2**: 2-meter specific humidity.
- **T2**: 2-meter temperature in K-s
- **U10, V10**: Cartesian components of daily 10-meter wind speed in [m s-1]

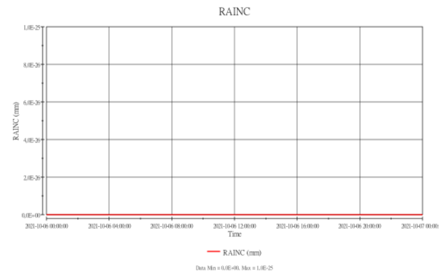
3.1 Temporal evolution

As a first part of this analysis we will study the evolution of our parameters throughout the day. For this we will use the Panoply program and we will apply the lineplot function, which makes an average calculation of the area of interest.

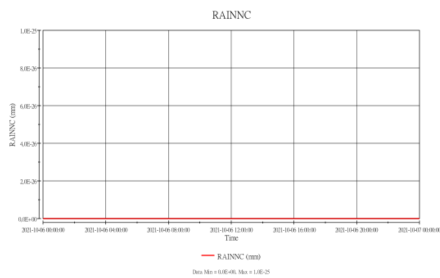
As we can see in the figure 1a, the mean cloudiness in our quadrant is null for any hour of the day. Furthermore, if we look at the graphs 1b and 1c we can see that both the values of convective and non-convective rainfall are null for the whole day. Therefore, we can rule out possible rainfall of any kind. Therefore, from this we can deduce that in general, and we say in general because we are calculating an average in the whole selected area, we will have a sunny day.



(a) CLDFRA vs time



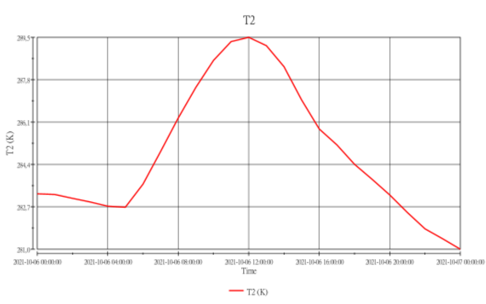
(b) RAINC vs time



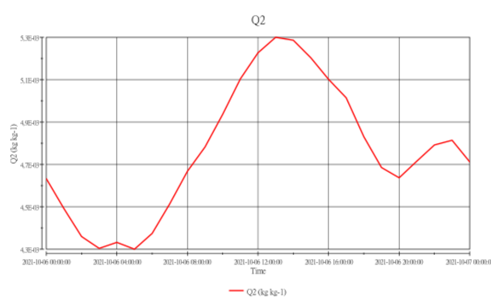
(c) RAINNC vs time

Figure 1: Line-plots for CLDFRA, RAINC, RIAINNC in St. Petersburg.

On the other hand, if we look at the values obtained for the temperature 2a, we can see that the average minimum temperature of the day is 281k-s (at 00:00) while the maximum is 299.5K-s (at 12:00). That is, we have a temperature difference of 18.5 degrees between day and night. Furthermore, if we look at the graph 2b we notice that the maximum of the specific humidity is obtained at a time a little later than 12:00 noon. In other words, the amount of water vapour contained in the atmosphere at two $2m - s$ above the ground reaches its maximum after the highest temperature of the day. In fact, the higher the temperature of the air, the more dissolved water vapour it admits.



(a) T2 vs time

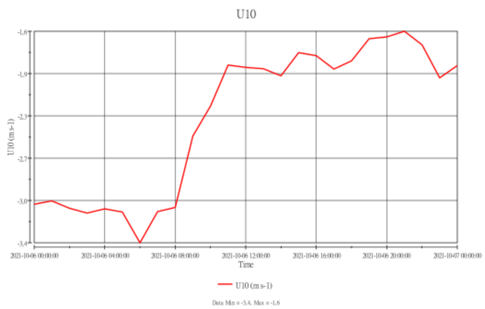


(b) Q2 vs time

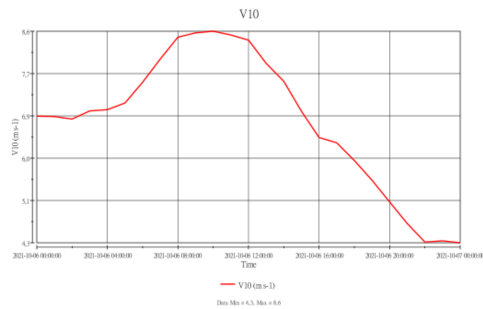
Figure 2: Line-plots for 2-meter specific humidity and temperature St. Petersburg.

From these two results we can deduce that the most intense hours of sunshine in our quadrant will be around midday.

Finally, as we can see in the images 3a and 3b, the absolute value of both, the zonal component of the wind (U) and the meridional component (V) decreases with the hours. The meridional component reach it's maximum at around 10:00 am. Furthermore, as the values of V are positive while those of U are negative, we can deduce that on average, the wind will blow from the southeast with a tendency to change its direction towards the southwest.



(a) U10 vs time



(b) V10 vs time

Figure 3: Line-plots for 10-meter zonal and meridional component of the wind in St. Petersburg .

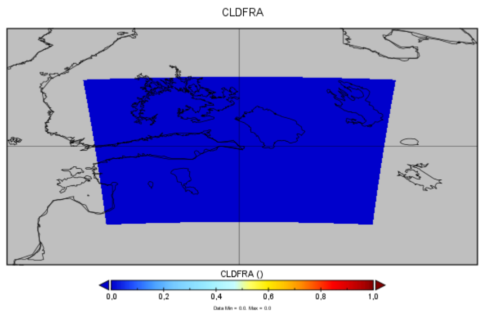
3.2 Spatial evolution

Although from the previous section we have been able to draw some conclusions on how our variables evolve throughout the day, these conclusions are only valid from a more general point of view.

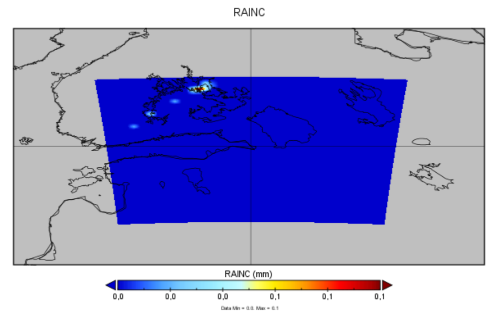
In order to see the local changes within our area we need to make a spatial study. To do this we will use the tool `Georeference lat/lon contour plot` from **Panoply**[4] software.

As can be seen in the images 4a, 4c and 4c (and as mentioned in the previous section) the values for the variables CLDFRA, RAINC and RAINNC are near zero over the whole area.

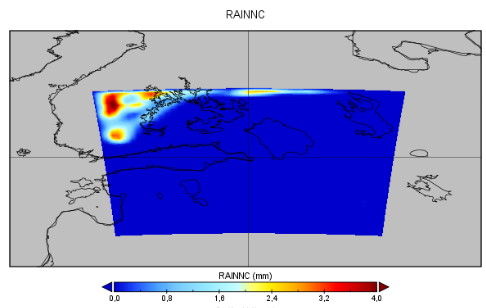
If we look at the centre of the quadrant, exactly where the city of St. Petersburg is located, we can see that there is no rainfall of any kind during the whole day. However, in the upper left-hand corner of the quadrangle, small amounts of precipitation can be observed from 21:00 in the evening onwards. These small drizzles are located in the south of Finland.



(a) CLDFRA



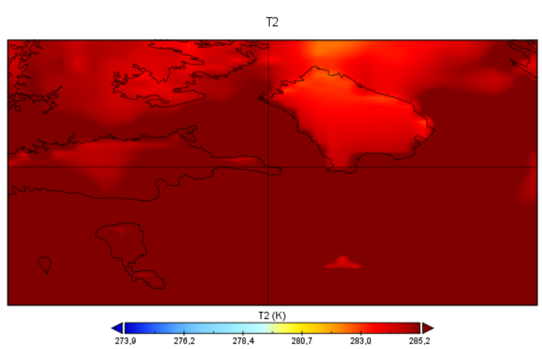
(b) RAINC



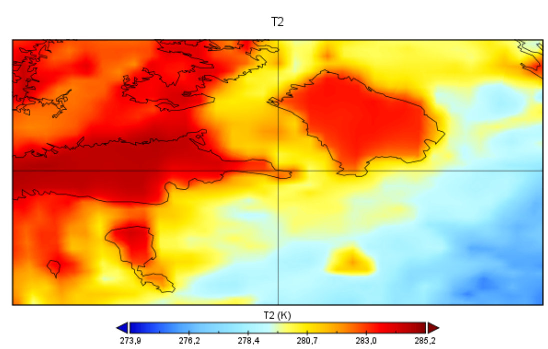
(c) RAINNC

Figure 4: Line-plots for CLDFRA, RAINC, RIAINNC in St. Petersburg.

In the case of temperature, as predicted in the previous section, the maximum value is reached at 12:00 noon, while the lowest temperatures are reached at night. As we can see in the image 5a these temperatures are distributed more or less homogeneously throughout the quadrant. In particular, we can see in 5b how, from 21:00 onwards, the temperature starts to drop drastically. However, as we can see in the south-eastern part of Finland (north-eastern part of the image) the temperatures are still high at this time of the night.



(a) T2 at 12:00



(b) T2 at 21:00

Figure 5: Line-plots for 2-meter specific humidity and temperature St. Petersburg.

On the other hand, as we can see in 6, the specific humidity remains relatively constant around the city (with a very low values). Moreover, the highest values of this variable are located in the northwest area of the image. As can be seen in figure 2b, from 21:00 there is a small peak. This is located in the southeast of Finland (upper right corner of the image 6).

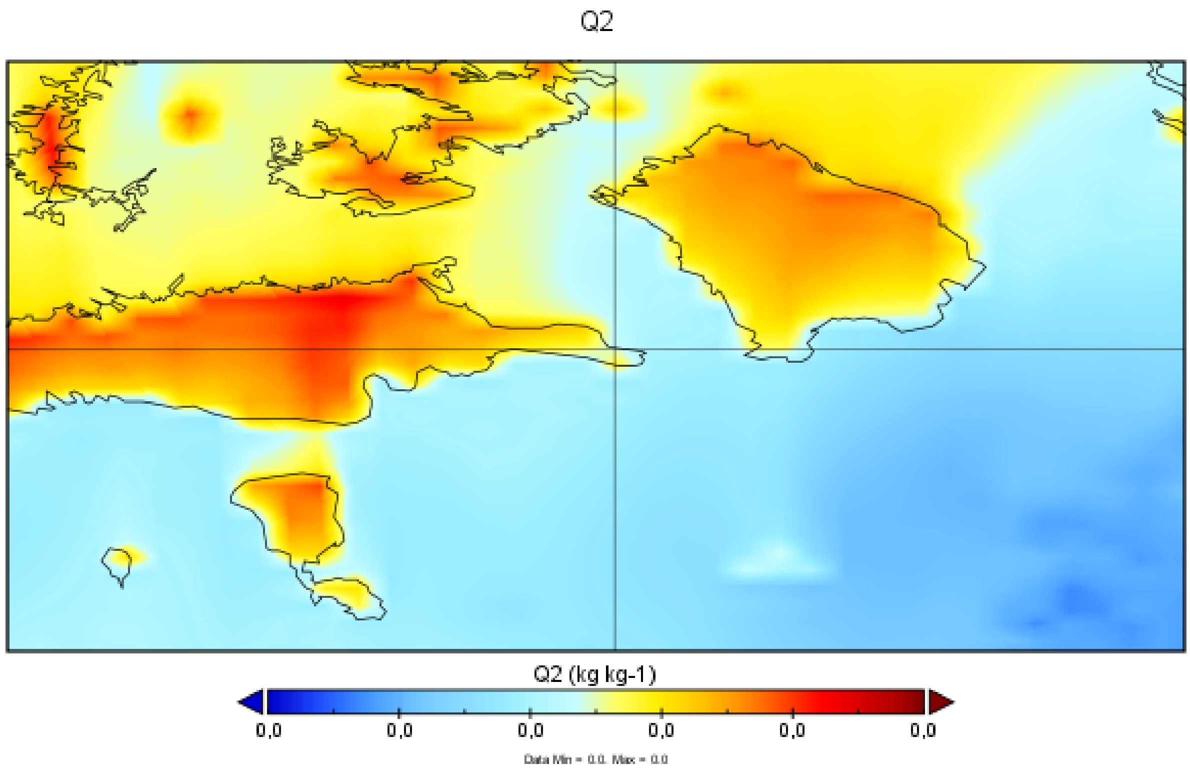


Figure 6: Q2 at 21:00

Finally, in the case of the wind, in order to see the evolution of both the meridional and the zonal components, we have created a gif in which we represent the vectorial sum of the two velocities point to point. In the sequence of images, it can be seen that in general, the wind blows from the southeast. However, as the day progresses, the wind direction changes in the right part of our area.

In order to see the giff click on the following link: WIND:GIFF

4 Conclusions

In this work we have made a weather forecast for the city of St. Petersburg on 06/10/21. The work has been divided into two different parts. On the one hand, we have run the model at latitudes and longitudes close to our site of interest. On the other hand, once the results were obtained, we interpreted them in both a temporal and a spatial context.

From the temporal analysis we have drawn several conclusions. On the one hand, both cloudiness and convective and non-convective rainfall have been null throughout the day. These values have been obtained hour by hour.

On the other hand, both temperature and humidity have shown low values both in the early and late hours of the day. In other words, the difference is clear for these two variables between day and night. It should be noted that in the case of temperature, the minima is set at 281 K-s while the maxima (obtained at 12 noon) is set at 299.5 K-s . Moreover, in the case of cloudiness, a small peak at 21:00 at night is remarkable. A peak that we have been able to explain in the second part of the analysis.

Finally, we have analysed both Cartesian wind components: U and V. From the vertical component we conclude that it reaches its maximum at 10:00 in the morning. However, from that time onwards, the intensity has been decreasing. As for the zonal component U, we have obtained negative values in the whole time interval. This means that the wind has been blowing on average in a westerly direction throughout the day. However, as the hours have passed, the intensity of this component has practically halved. This gives us a clue that in several parts of the map, there is a change in wind direction.

In order to better understand the behaviour of the variables in different zones of the established area, we have analysed the distribution of the parameters along the map.

On the one hand, as expected, most of the map shows a null value in precipitation. However, from 21:00 in the evening onwards, small precipitation appear in the southern part of Finland. This may be due to several things. Firstly, we have found that although the temperature drops drastically during the night, the north-western part is the warmest part of our region of interest. Therefore, from 21:00 on-wards, the atmosphere becomes cooler, the ground keeps the heat received during the day and the specific humidity in this area increases. This can lead to the occurrence of light rainfall in this zone. However, the intensity of the rain is not very high, which gives us the idea that they are of the non-convective type. Secondly, the explanation for these high temperatures comes from the wind. In general it has been blowing from the southeast all day long, however, there has been a slight change in both direction and intensity from the late afternoon onwards.

References

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[4] NASA GISS: Panoply Data Viewer: Downloads. Giss.nasa.gov. (2022). Retrieved 21 January 2022, from https://www.giss.nasa.gov/tools/panoply/download/.